FIELD EVALUATIONS OF IMMERSIVE COMMAND AND CONTROL (C2) APPLICATIONS

Mark Ferneau* and Mark Gill
Mechdyne Corporation, Government Relations
4801 Hampden Lane, Suite 104, Bethesda, MD 20814

Ray Schulze and Ron Kane
U.S. Army RDECOM CERDEC C2D
AMSRD-CER-C2-BA, Fort Monmouth, NJ 07703

ABSTRACT

Large scale immersive visualization environments developed for Future Force Warrior (FFW) and Future Combat Systems (FCS) will dramatically increase the volume of data available to commanders. At the same time, immersive three dimensional (3D) visualization stereoscopic technologies can improve the commander's ability to comprehend this avalanche of information and act upon it quickly and decisively. Advanced visualization and interaction technologies will also support the commanders' need for mission planning/rehearsal, situational awareness and after action reviews.

The U.S. Army Communications Electronics Research Development & Engineering Command (CERDEC) Command & Control Directorate (C2D) has developed several immersive C2 applications to support the future commander's ability to make decisions faster and more accurately. Utilizing a Fakespace stereoscopic three-dimensional (3D) C4ISR (Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance) Automated Virtual Environment (CAVE) Laboratory and a Fakespace Rapidly Operational Virtual Reality (ROVR™) system, C2D has done extensive research in its lab located at Fort Monmouth, NJ and in the field at the C4ISR On-The-Move (OTM) 2006 Experiment conducted at Fort Dix, NJ.

1. INTRODUCTION

The CERDEC C2D CAVE Lab was created in 2004. Since that time the team, which consists of government and contractor personnel, has been conducting research and development in the application of immersive technologies and advanced visualization techniques to assist commanders in their decision-making processes.

To date, the CAVE team has built, using commercial-off-the-shelf (COTS) equipment, a room-sized immersive environment, see Figure 1, and the highly mobile, ruggedized ROVR™ system, see Figure 2, which can be scaled to meet specific user needs. The team has also developed software, the Immersive Interactive Command & Control Environment (I2C2E), and the C2 Two-Handed Interface (C2THI) for the presentation and manipulation of stereoscopic 3D scenes. The team has also developed a tactical message parser and database that allows for the reception and storage of tactical data, and an interface to the I2C2E for the display of that data in the 3D environment.

Figure 1. The CAVE®

Figure 2. The ROVR™

2. THE C2D ROVR SYSTEM

A single ROVR consists of a large 6' x 7.5' projection screen, a high-bright three chip digital light processing (DLP™) projector and a computer that

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
01 NOV 2006	**N/A**	**-**

4. TITLE AND SUBTITLE	
Field Evaluations Of Immersive Command And Control (C2) Applications	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Mechdyne Corporation, Government Relations 4801 Hampden Lane, Suite 104, Bethesda, MD 20814**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002075., The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**6**	

contains the system software necessary to drive the projectors. The ROVR™ supports active or passive stereoscopic, or monoscopic viewing, and can support rear or front projection.

The C2D ROVR™ consists of three edge-aligned, rear projection ROVR™ systems. It includes three 2,000 lumen (brightness) 3-chip DLP™ projectors and a four computer cluster that includes three nodes to drive the projectors and a master computer to coordinate and control the nodes. For user navigation and orientation in the scene, the system uses an InterSense IS900 inertial acoustic motion tracking system with a six degree-of-freedom (6DOF) tracked wand.

The ROVR™ is highly mobile and ruggedized. Each screen and frame fits neatly into a duffle bag-like carry case and each projector is mounted in an Air Transport Association (ATA) category 1 case. The ROVR™ system is easily transportable in most truck-style vehicles. When fully assembled and setup in the arena layout the C2D ROVR™ system's footprint is approximately 6.5' x 26' x 9'.

3. THE C2D APPLICATIONS

C2D's application software permits the user to interact with the simulated environment. The basic functionalities include the terrain models that provide the 3D simulation of the modeled area; a user-interface that permits selection of the operating mode, live or playback; the Event Data Manager which receives, stores and forwards tactical messages; and the presentation software which displays the scenes and permits the user to interact with the immersive environment.

3.1 Terrain Models

The focus of the terrain model development was on several training ranges located at Fort Dix, NJ where initial field testing of the ROVR™ system and the application software was performed during the C4ISR OTM 2006 Experiment. Selection of the specific ranges was coordinated with the Product Manager (PM) C4ISR OTM who conducts the annual experiments at Fort Dix.

For this effort data collection was performed using a manual process. This consisted of visiting each range with a global positioning system (GPS), a laser-based distance measuring device and a digital camera. At each range the location of each structure was documented using the GPS. A structure is defined as all permanent features of the range including buildings, bunkers, vehicles, etc. The dimensions of each structure were also measured and photos of each structure were taken from various angles and distances.

Utilizing the collected data, a 3D modeler constructed high-fidelity models of each range using the Autodesk 3DS Max and Newtek Lightwave modeling software packages, see Figure 3. Using terrain data of the Fort Dix, McGuire Air Force Base and Lakehurst Naval Air Station area from the United States Geological Survey (USGS) the range models were precisely geo-located on the USGS map. This allows users to navigate from range to range with no discontinuities in terrain. The entire modeling effort for the ranges utilized in the C4ISR OTM 2006 Experiment took approximately four months for a single 3D modeler.

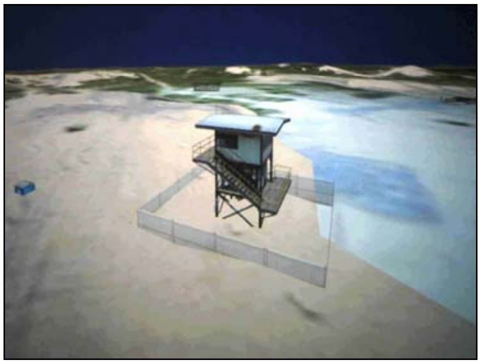

Figure 3. Tower model

3.2 The User-Interface

The user-interface (UI) has two primary modes: Live Mode and Review Mode. Live Mode displays tactical messages and unit positions in real time. Review Mode provides the operator with the ability to view past events and positions. The operator can toggle between these two modes depending on which one supports the task they are trying to accomplish.

In both modes, the UI presents the operator with a DVR-like (digital video recorder) interface. The interface allows the operator to move to and begin playback from any point in the specified mission. The UI also has fast-forward, rewind and pause features as well as the ability to adjust playback speed from 1x to 64x. When the UI is in Live Mode, these controls allow the operator to temporarily back up to any point in the mission and then quickly return to live data.

In order to decrease visual clutter, the UI allows the operator to filter out entities individually or as a collection specified by type (e.g. UAV, UGS), name or reporting hierarchy.

While the C2D application allows operators to freely navigate throughout the terrain, it is often useful to quickly jump to a pre-defined location. The UI allows the user to store named locations for instant navigation at a later time.

3.3 The Event Data Manager

The Event Data Manager (EDM) provides the mechanism for interfacing the system to the tactical network, receiving and parsing tactical messages, storing tactical data and injecting tactical data into the system for display. Currently the EDM provides receive-only capability.

Development of the EDM was coordinated through the PM C4ISR OTM to ensure it implemented the proper messaging standard for the 2006 experiment. The implemented messaging standard is the variable message format (VMF) series of messages. VMF is a bit-oriented tactical message standard which specifies how tactical data is transmitted, received and displayed. The types of messages received were Blue Force (BluFor) position reports and Opposing Force (OpFor) spot (entity data) reports.

After parsing a VMF message, the tactical data contained within is stored in the EDM database. If the system is operating in live mode, the tactical data is injected directly to the application software for immediate display.

In addition to storing tactical data, the database contains additional information which describes the mapping of an entity to its specific *Standard Warfighter Symbology* (MIL-STD-2525) symbol and physical representation, e.g. soldier, ground vehicle, air vehicle, etc. icon.

3.4 The Presentation Software

The presentation software fuses the terrain, structure and entity models with input from the UI and EDM to complete the immersive environment. User input from the 6DOF wand, tracking system and UI allows navigation within and control of the 3D scene.

The presentation software has been designed to take advantage of the unique features of a large scale, fully immersive and interactive environment. For venues which offer limited options for a display system, the presentation software is capable of running on a single laptop or desktop computer.

The scalability of the solution is critical as it allows users in disparate locations with systems of varying capabilities to use the same, familiar application and UI.

4. C4ISR OTM EXPERIMENT

The CERDEC C4ISR OTM Experiment is conducted annually in an operationally relevant environment using live, virtual and constructive scenarios. The experiment is designed to identify and mitigate risks to current force technology insertions and FCS spinouts early in the development cycle.

The C4ISR OTM 2006 Experiment was conducted from 10 – 17 July and consisted of a representation of a FCS reconnaissance troop supported by a squad-sized infantry quick reaction force. This Blue Force consisted of soldiers from the 2nd Battalion, 113th Infantry of the New Jersey Army National Guard. The OpFor was an insurgent-style enemy force.

Each day was characterized by a unique mission designed to test the operational functionalities of the C4ISR equipment. Each daily run consisted of a pre-mission briefing, execution of the mission, a mission debrief and a mission planning session for the next day's mission.

The pre-mission brief provided the Blue Force with their mission objective, any intelligence known about the OpFor and instruction on how the Blue Force would advance on their objective. During execution of the mission C4ISR assets were deployed in such a way that the quality and fidelity of information provided to/from the Blue Force was varied to study the effects on the network and the commanders' ability to attain situational awareness and make effective decisions.

After each mission a debriefing, referred to as the daily hot wash, was conducted. The debrief was a recap of the day's events and observations made in the command post and the field that were relevant to the performance of the C4ISR equipment and the soldiers' use of that equipment.

Each day ended with a mission planning session for the next day's mission. During these sessions commanders, platoon leaders and platoon sergeants would discussion the mission's objectives, how they would deploy their C4ISR equipment and what tactics they would use to accomplish their objectives.

5. ROLE OF THE ROVR

The ROVR™ supported the experiment as an advanced visualization tool for conducting mission planning, situational awareness (SA) and after action reviews (AARs). Although ROVR™ team members evaluated both the system's ability to provide accurate SA during mission execution as well as properly replayed data for AARs, the only evaluation performed on the ROVR™ in terms of its impact on mission execution was during mission planning.

5.1 Mission Planning Session

Due to its ability to display of high-fidelity terrain models, the ROVR™ system was utilized to perform scenario simulation for a mission that was executed at a Military Operations in Urban Terrain (MOUT) site. The objective of this planning session was to evaluate the impact of using the ROVR™ system on planning and execution of the mission.

The planning session was attended by the Platoon Leader, Platoon Sergeant and the Robotics NCO. The goals of the session included determining the best locations for placement of UGS, identifying suspected enemy strongholds and safe houses, determining the best routes of ingress and identifying a possible foothold in the site for the FFW Infantry Platoon. Figure 4 shows the mission planning session.

Figure 4. Mission planning session

To expedite the session, experienced ROVR™ operators performed navigation tasks with the 6DOF wand to alleviate the need for training. Following the planning session, soldiers were given the opportunity to use the wand so that feedback on its use could be attained. Figure 5 shows a soldier using the 6DOF wand.

Figure 5. Soldier using 6DOF wand

The first task for the soldiers was to get a general orientation of the layout of the MOUT site and determine the best locations to place their UGS. The ROVR™ operator flew them over the site to get an aerial view, see Figure 6.

Figure 6. MOUT aerial view

From the aerial view the soldiers could identify routes leading into and out of the MOUT site. As the system allows the operator to freely navigate within the environment, the soldiers used a birds-eye view of the MOUT site street layout for improved orientation. Based on intelligence reports soldiers could predict where enemy forces would enter the site and were able to determine approximate locations for their UGS.

In order to provide the soldiers with a closer look at the terrain for UGS placement, the operator navigated down to a dismount or first-person perspective street level for a closer inspection. Once the inspection task was completed the soldiers walked through the streets of the site virtually to determine best routes, identify specific buildings, and identify any obstacles that may impede their movement. Figure 7 shows a street level view of the MOUT site.

Figure 7. MOUT street level

The soldiers then walked around the suspected enemy safe houses and strongholds to determine entrance ways, windows and learn the general characteristics of each building from all four sides. They then identified a potential foothold for the FFW Platoon. They were able to learn the general layout of that location and identified routes of ingress and egress to/from the building. Throughout the mission planning session the Robotics

NCO took notes and drew diagrams of the MOUT site. After the planning session the three leaders returned to their troops to train them using their notes and maps of the MOUT site.

5.2 Soldiers Response to ROVR™

"Each of the three leaders stated that this planning session was a great benefit to their planning. The Platoon Leader estimated that the technology improved his planning capabilities by 75%. The Platoon Sergeant stated that the technology is outstanding if it is accurate and up to date. He thought the colors and shapes of the buildings and the layout of the streets was very helpful. His estimate of how this improved their planning was 70%. The Robotics NCO estimated that the ROVR™ planning was 80% better than using a sand table" (E. Bowman, Personal Communication, 4 Aug 2006). The soldiers did note some drawbacks to the session. The Platoon Leader said that he initially got a headache from some of the extreme movements through the scene. ROVR™ team members noted that this is typical for some new users due to the stereoscopic 3D view and navigating through the scenes too quickly. Other comments were suggestions for functions that the soldiers would like to have built into the system. These functions include the ability to draw on or markup a scene, the ability to measure distance between two points, and the ability to print out a marked-up map. The ability to markup a scene is available in the Two-Handed Interface (discussed below), however, that software release was not available at the time of the mission planning session.

5.3 Mission Execution

"On the morning of the MOUT mission, the Platoon Sergeant was confident in the locations of the buildings of interest in the area and knew where his soldiers and unmanned assets were to be placed. This technology provided an excellent tool for the Soldiers to become familiar with the layout of the MOUT site" (E. Bowman, Personal Communication, 4 Aug 2006).

When the Recon platoon arrived at the MOUT site to execute their mission they did so with very little deviation from their plan, "the PacBot had to be manually placed on a rooftop because there were no stairs in the building. Otherwise, Soldiers and systems were emplaced according to plan."

"The Soldiers' consensus on the ability of the ROVR™ technology to improve planning and execution was very favorable. They would like to use it more in the future. The visualization technology is realistic and it is helpful to have different views (ground and air)" (E. Bowman, Personal Communication, 4 Aug 2006).

6. C2 TWO-HANDED INTERFACE

The C2 Two-Handed Interface (C2THI) application is focused on extending the 3D C2 environment by adapting distributed immersive collaboration capabilities. This will enable remote commanders to perform advanced mission planning/rehearsal as if they were all sitting together in the same room.

With the SpaceGrip® interaction device, hand-held devices that communicate hand position and orientation, users of the system navigate through scenes using the natural movements of their hands and arms. Figure 8 shows how well SpaceGrips® fit comfortably in each hand.

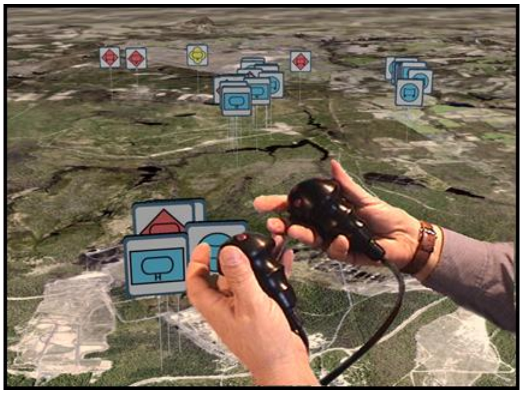

Figure 8. C2THI SpaceGrips®

When collaborating together, remote users show up as robot-like avatars in the other users' scene. Each user can mark up a scene with tactically relevant information using the 3D white board. The white board is then shared with each participant. Using the SpaceGrips® participants can even gesture to each other. Figure 9 shows a marked up screen, i.e. the locations of Blue and Red controlled areas and a remote user's avatar.

Figure 9. C2THI collaborative session

7. THE WAY AHEAD

Leveraging the successes of the 2006 experiment, the CAVE team will continue to develop its hardware and software to meet the needs of the soldiers for whom it is intended. Feedback from soldiers and analysts will guide the coming year's development.

The CAVE team will address the feedback from the soldiers who used the ROVR™, such as being able to export marked up scenes to other Army Battle Command Systems as Overlay messages. We will add capabilities such as overlaying grid lines on the terrain and the ability to "hook" a track and receive detailed information about an entity.

The CAVE team will also address hardware issues such as the "footprint" of its current systems. Fakespace is currently developing increasingly portable systems that may be more suitable for placement within smaller operations centers without losing the immersive effects of the current ROVR™.

The CAVE team will continue to improve the visual fidelity of the modeled 3D Fort Dix environment through the introduction of more ranges and extensive foliage. A more automated method of 3D data acquisition and model creation will be investigated and applied.

Finally, the CAVE team will seek to perform a more extensive field evaluation of its systems at the C4ISR OTM 2007 Experiment including the areas of situational awareness and after action reviews.

8. CONCLUSION

Immersive display technologies have the potential to assist commanders in receiving and understanding large amounts of tactical data. Initial testing and results from the C4ISR OTM 2006 Experiment indicate the soldiers liked its capabilities, and thought the ROVR™ was a vast improvement over current mission planning methods. During the planning session leaders used aerial views to provide a "broad view to plan initial sensor/soldier placement. Soldiers used the street-level views to walk around buildings and finalize their plans" (E. Bowman, Personal Communication, 4 Aug 2006).

Observations during the execution of the mission indicate the ROVR™ solution was instrumental in assisting soldiers to move through the area of interest and emplacement of assets. "Benefits for execution were greater knowledge of the objective area, increased confidence, shortened time for emplacement of technologies by soldiers, and rapid identification of key buildings based on color shape and location" (E. Bowman, Personal Communication, 4 Aug 2006). The ROVR™ planning session resulted in the soldiers spending less time in harms way with increased effectiveness.

ACKNOWLEDGEMENTS

The authors of this paper would like to thank the CERDEC leadership, Mr. Gary Martin, CERDEC Director, and Dr. Gerardo Melendez, C2D Director; and the PM C4ISR OTM, LTC William Utroska, and his staff for enabling the CAVE team to develop its systems and participate in C4ISR OTM 2006 Experiment. The authors would also like to thank Dr. Elizabeth Bowman, Army Research Lab, for her expert analysis of the ROVR™ technologies while observing the soldiers utilize it for mission planning and her field observations during the execution of their missions. Finally, the authors would like to thank the entire CAVE team from CERDEC, Lockheed Martin, Mechdyne Corporation (including subsidiaries Fakespace Systems and VRCO), JB Management, Digital ArtForms and Future Skies. Their Herculean efforts during the months leading up to and during the C4ISR OTM Experiment made the entire field test a huge success.